THE ALL-INDIA VILLAGE INDUSTRIES ASSOCIATION

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GRINDING OF CEREALS

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MAGANVADI
WARDHA, C. P.
1947

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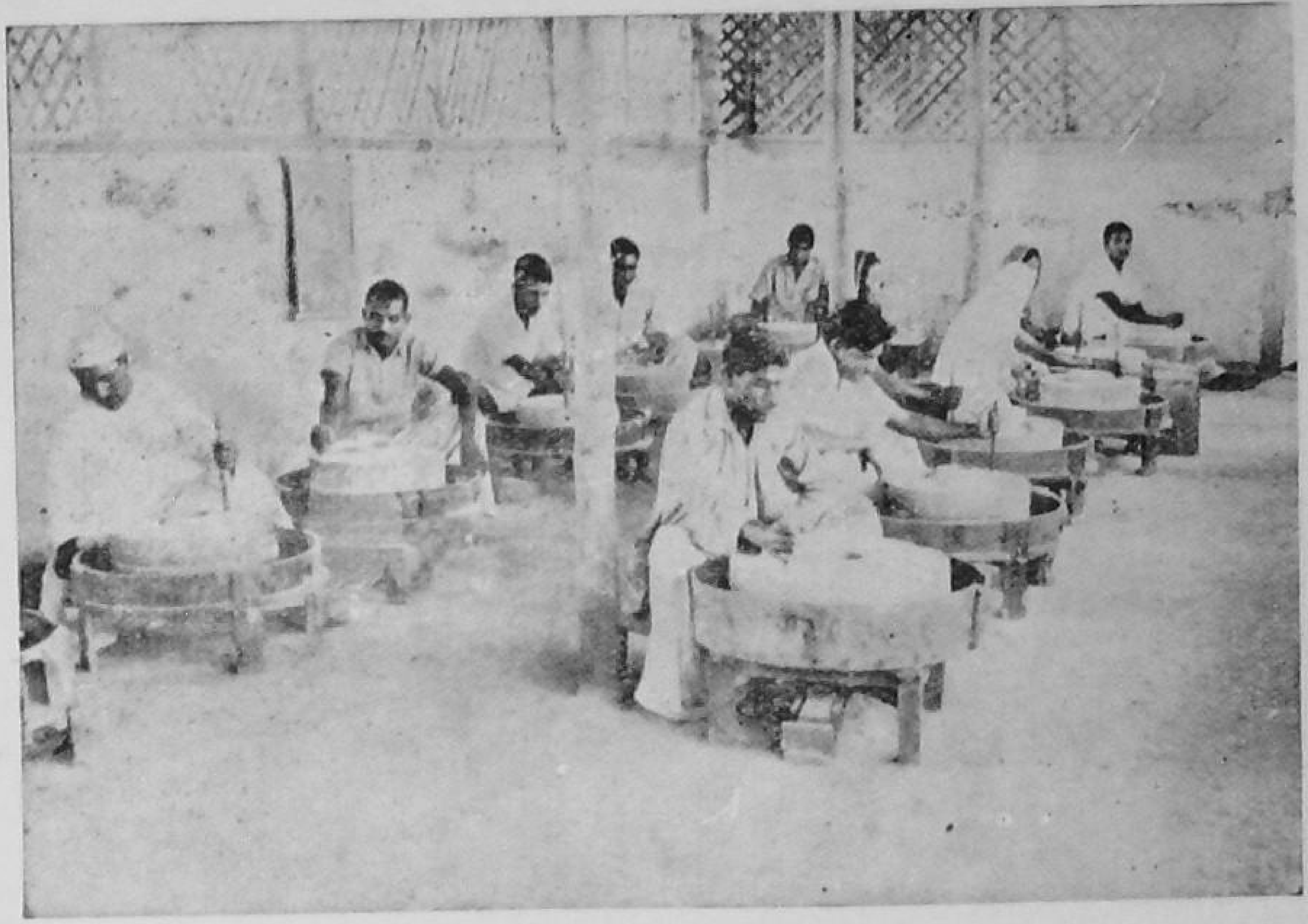
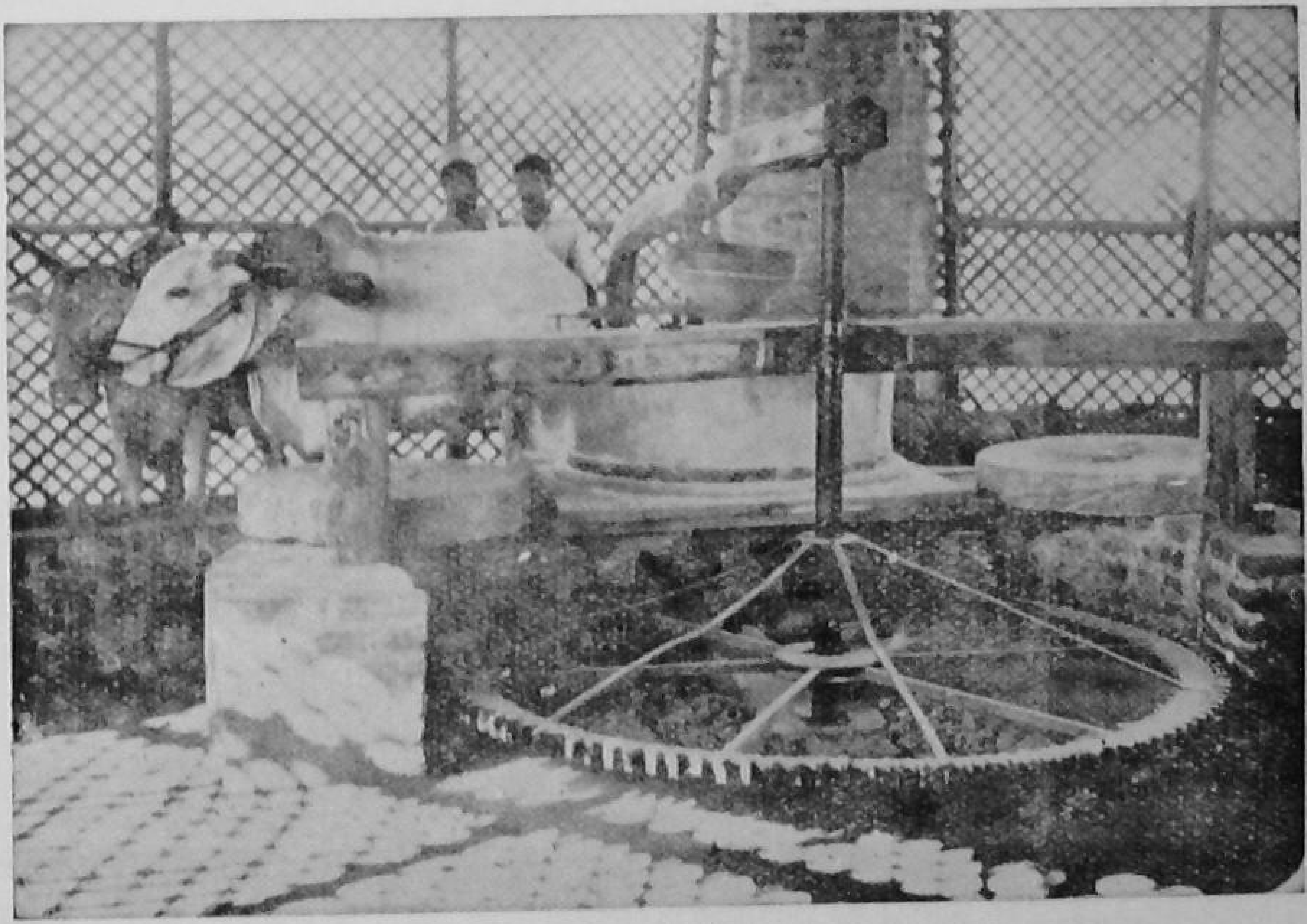
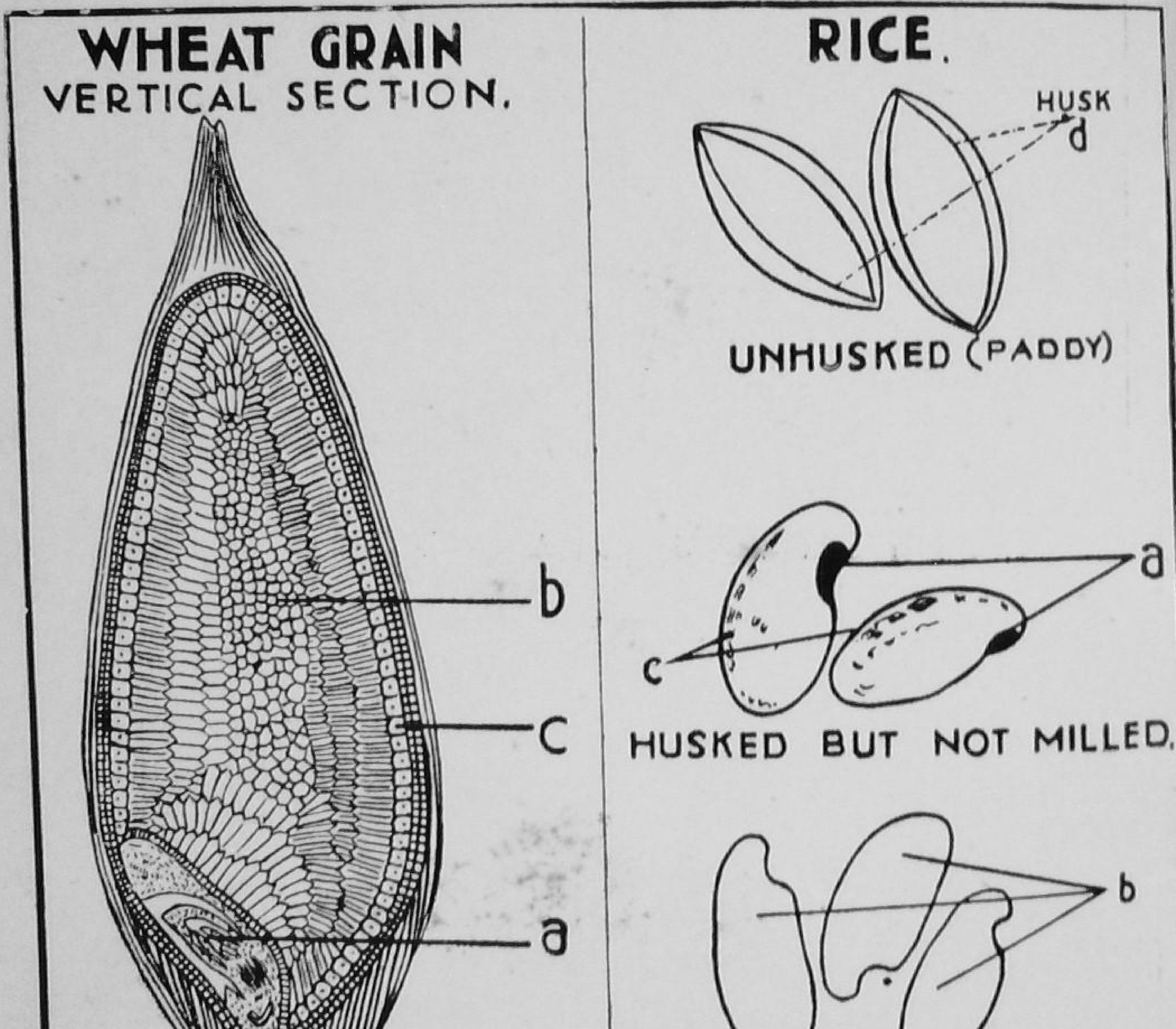


Flour Grinding Section A. I. V. I. A.



Punjab Bullock Chakki


WHEAT GRAIN
VERTICAL SECTION.
b
c
a
d
RICE.
HUSK
d
UNHUSKED (PADDY)
a
c
HUSKED BUT NOT MILLED.
b
MILLED AND POLISHED

GRINDING OF CEREALS

Food, when taken in the human system, undergoes many chemical and bio-chemical reactions, which ultimately break it up into such simpler constituents as can be directly taken up by the body. The digestion that goes on in our system, can be helped by processing of food materials by grinding, cooking; and when carrying out these processings we have to take care that none of the nutritional elements are lost.

All cereals have cellulose cell walls in which starch is packed and an outercoating and the germ portion. The layers of the cell just below the outer covering, are rich in protein. vitamin and mineral salts. The tenacity with which these layers in the cells are held, varies with different varieties of the cereal. To help the digestive juices to react with the food packed in these cells, the cell walls have to be ruptured and the food matter broken up as far as possible. This will make the work of the digestive organs easier. These are termed pre-digestion processes.

In the case of wheat the outer coating is an elastic and tough cellulose membrane. This, unlike rice, is hard to be dissolved in the chemical juices of our body, and even after grinding there remains roughage in the flour, and this is essential for the proper cleaning of bowels. Thus in grinding, the upper coat is shattered and all the inner cell walls smashed, opening up the food in it to be acted upon by our digestive juices. Under this coat there is a large number of cells rich in proteins, mineral matters and the germ parts and this portion is rich in vitamin B_1 and E. The vitamin B is one of the most essential food factors and is required for right functioning of internal organs like the

heart, the digestive system and all such where contraction and expansion take place. The disease Beri Beri is caused by a deficient supply of vitamin B_1. For general tone of the health also, this vitamin is mostly responsible. The vitamin E is said to be protection against sterility.

Vitamin B cannot stand a temperature of more than 100-110°C. So in our processing we ought not to loose this by subjecting it to a temperature it cannot stand. Unfortunately this is what actually happens between the fast running rollers or stones of a flour mill. Anyone who has touched the flour as it comes out of the mill, has experienced how unbearably hot it is, and can well imagine that in the mill, during the process of attritional grinding, it must have been even higher though only for a short period of time. It can be safely asserted that during milling operation in a flour mill, the temperature of the flour reaches to about 100-120°C. This means there is certainly a loss of vitamin B, in the resulting product. Here is an example of wrong processing. Our country folk have always been taking hand ground "Atta", which process provided the women with a healthy light exercise im the morning and a healthy food to the family.

When wheat is ground in the hand-driven chakki, the speed of the stones is never great and the frictional heat resulting is practically imperceptible. Hand ground flour retains all the health giving ingredients present in the wheat.

It may be asked if the temperature of the flour does not rise over 100°C when "the chapatis" are being baked? No it does not; for, before baking the flour is first kneaded with water and during baking not all the water is evaporated, and untill all the water had evaporated the temperature will not exceed 100°C, the boiling point of water

In the case of rice we do not make it into flour because the cell walls are not so strong and there is no tough outer covering. The process of cooking tends to burst the cell walls and hydrolyse the starch to simpler sugars.

These simple facts, if kept in view, will help us to save much that is now lost due to defective and wrong processing In a country like ours, where most of the nutrition is derived from cereals, it is criminal on the part of mill owners to destroy the nutrition of even this source for trifling considerations of colour and profit motives.

IMPROVED CHAKKI
EVOLUTION, STRUCTURE AND MAKING

Wherever rice is not prevalent as a staple food, wheat, juar, jau and such other cereals take its place. There. is a sharp difference in the dressing of rice and of wheat for the table. Riee becomes fit for consumption after boiling it in water for a time. But wheat and other cereals are not treated that way. They are ground into fine flour, to which is added a little water, kneaded and baked into chappatis and bread etc. So this difference in the processing of cereals brings us to discuss this industry of cereals grinding.

Wheat is consumed commonly all over our country excepting in a few tracts like Tamilnad, Bengal, Assam & Orissa. So the process of grinding is generally prevalent in all the places. Even in tracts where only rice is consumed, stone chakkis are quite common. The reason for this is that the poorer classes of people, who constitute the bulk of the population, have always depended on some kind of millet which is usually ground in chakkis. This is a part of the household work and is generally done by the women folk. People

have adopted or modified the chakkis according to the lecal conditions, the availability of the stones and nature of the cereal to be ground. That is why we find simple crude chakkis are being used. In the other wheat eating tracts, we find the people having better implements, We have nothing to trace the history of the invention of any process of grinding. But we can take it to be as old as the cultivation of wheat.

The time honoured implement used for grinding cereals is the chakki made of two circular discs of stone. The discs are placed one above the other and the cereals are fed in between them to get crushed by the upper disc being rotated at a speed. The lower one is fixed to the ground. In the middle of this stone is fixed an iron or wooden axle, around which the upper stone rotates. The upper stone has to have a sufficiently big opening in the middle for feeding the cereals. This is called the mouth of the chakki. The mouth of the chakki is partially blocked by a piece of wood called 'mani', which has a small opening in the centre to fit into the axle. The axle in the lower stone and the 'mani' in the upper one ensures the even motion of the chakki.

A wooden handle is fixed to the top of the upper stone and with its help the chakki can be rotated by supplying suitable force to it by hand. Generally these chakkis have a plain working surface which is a drawback in them. The cereal that enters the mouth does not get distributed and crushed in between the two stones.

Secondly, very little cereal enters the working surface and they get crushed into a fine flour very near the mouth itself. Then this flour has to travel the whole radius of the chakki before it finally gets out. This involves unnecesssary

" Desi " Chakki Fixed on the ground

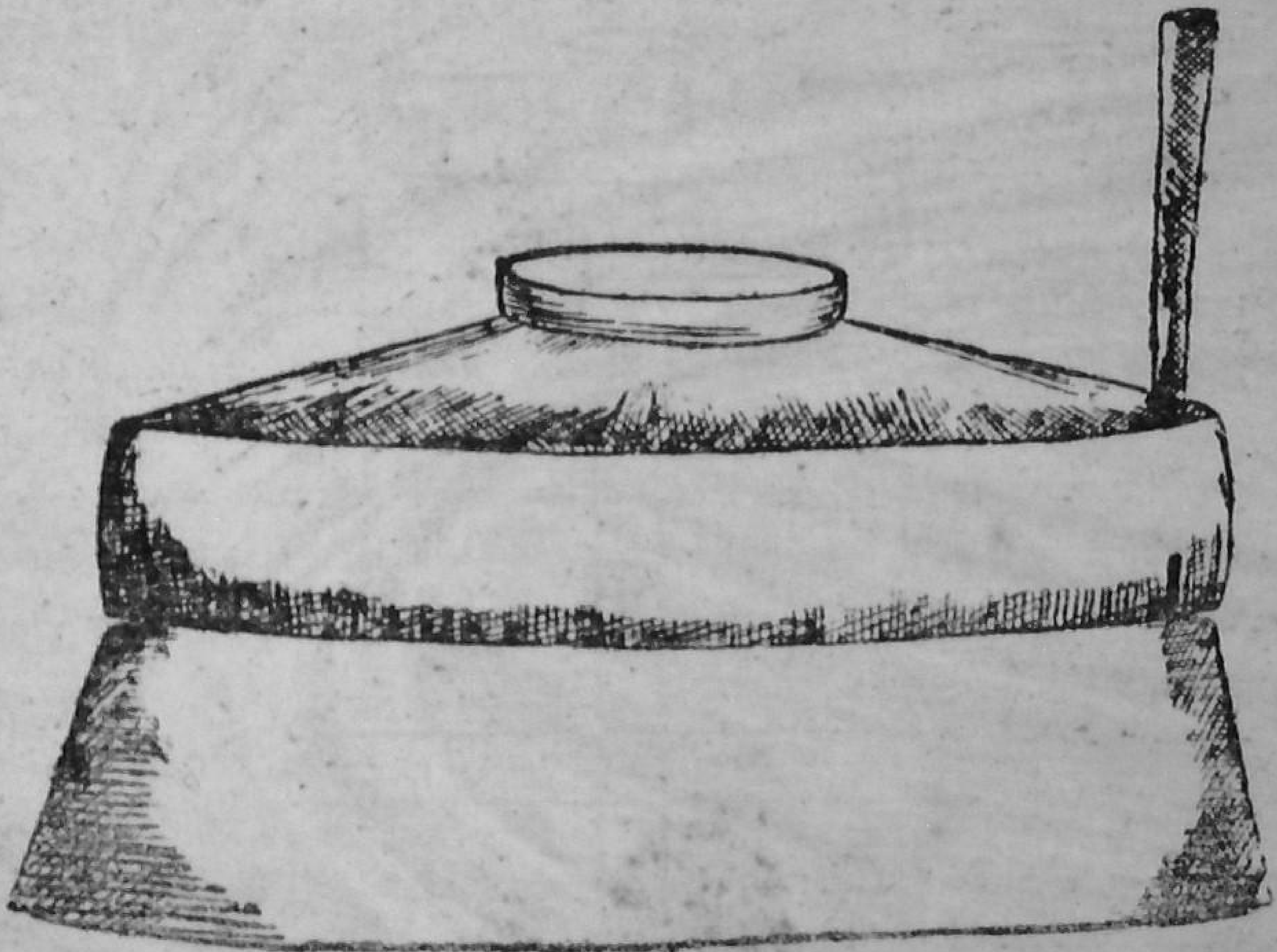


Fig. 8

There is no provision to collect the flour before it gets mixed up with the dust and dirt.

Desi Chakki Mounted on a Cross

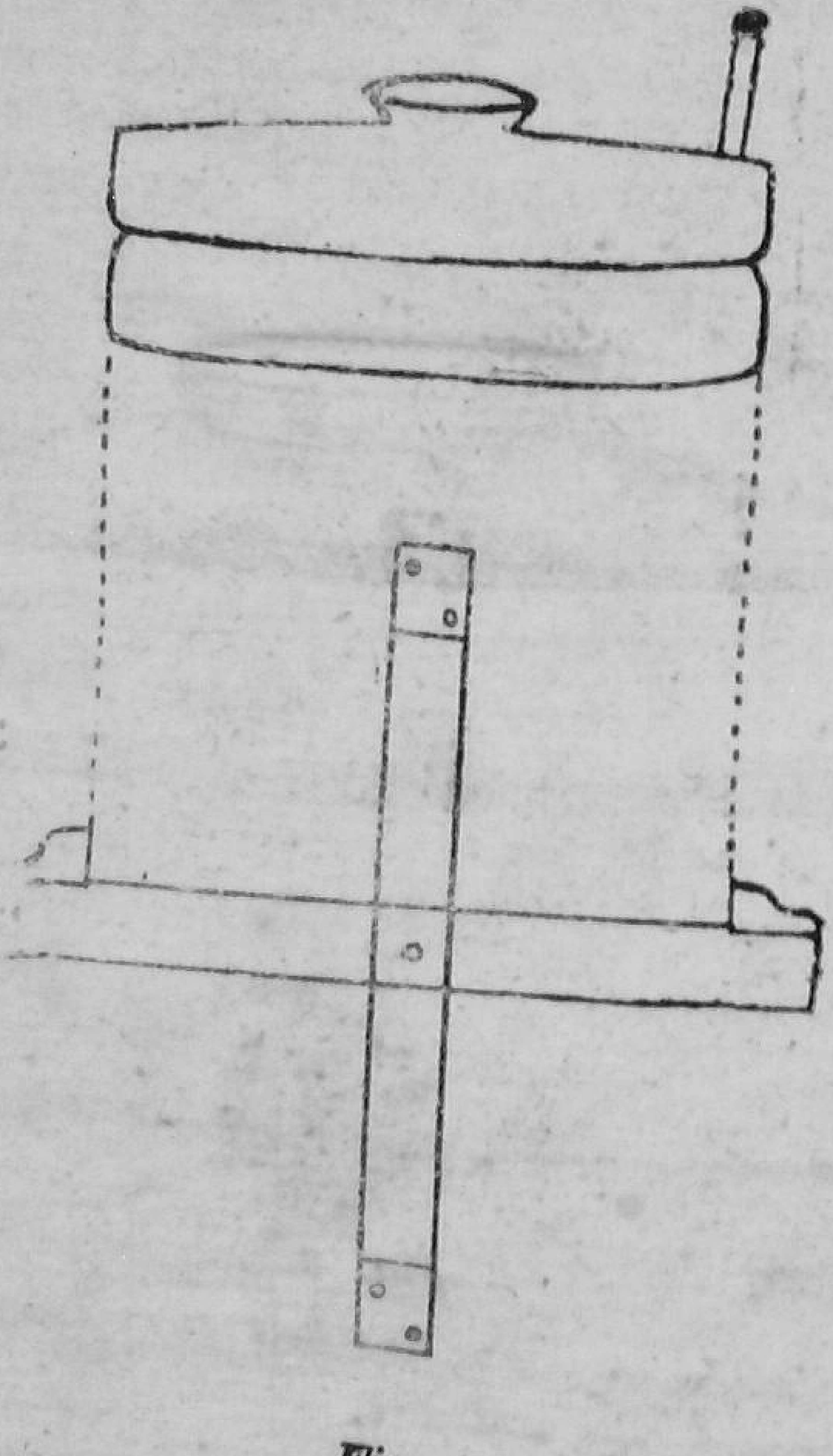


Fig. 4

labour in grinding, as the flour has a tendency to stick to the walls of the chakki. Due to these defects very little flour is ground inspite of doing hard work. There is no provision to collect the flour in a clean receptacle. It is allowed to fall on the ground and naturally gets mixed up with dust and dirt. No wonder people discard this in disgust as a crude machine.

We shall remember these defects in trying to improve the chakkis.

First of all the chakkis should not be fixed on to the ground as we cannot collect the flour before it mixes up with the dust etc. Also it should be portable. A small cross, like the one shown in the diagram, can be made and the lower stone can be fixed on to it. This arrangement makes it easy to keep the chakki anywhere we like on a clean piece of cloth or wooden plank to work it.

We have pointed out how a plain working surface in the chakki impedes the grinding process. So now it becomes necessary to allow enough space for the cereals to be properly distributed on the working surface. For this the lower stone can be made a little convex in shape. This will also aid the flour to travel down quickly.

When the working surface in the lower stone is made convex the working surface in the upper one ought to be concave to bring them in contact and crush the cereals. It is necessary to dress the working surfaces as shown in the figure.

Near the mouth the opening is broad enough to allow one whole wheat grain to enter. This opening gradually goes on lessening as it approaches the ends. The stones touch each other near the outer circumferences. During grinding the wheat enters the mouth of the chakki and gets gradually

broken up into finer and finer particles and gets completely pulverised near the circumference, and immediately after that falls down into the receptacle.

Improvements in the axle and mani :—

The axle and mani should not be too big as that will add to the friction already present. These should be, as far as possible, thin and strong. Iron axle and mani are common all over. They can also be made out of some strong wood as 'Khair' or 'Babul' etc. An ordinary frictionless axle can be ½" in diameter with one tip properly rounded up and made a little tapering. The 'mani' is an iron cube 1"x1"x1" with a small pit, say ½" deep, just enough for the tapering end of the axle to fit in and rotate without much friction. This iron cube is, in turn, fixed rigidly on a piece of wood, the length of which is equal to the width of the mouth, and is about 2" thick and 2" broad. This wood with iron cube is called the 'mani'.

People speak of reducing the friction in the chakki by substituting ball bearings etc. in the 'mani' instead of the ordinary iron or wooden ones. This is totally unnecessary when we understand the fact that the greatest amount of friction caused in the chakki is due to the grinding. This friction, caused by defective or a crude axle and mani, will be very small. Therefore not much advantage can be secured by substituting the axle and mani itself by a costly ball bearing system. Besides their being foreign, costly and therefore not within the reach of our villagers, they are quite unnecessray in a hand driven flour chakki. These costly and accurate bearings are intended where tremendous speed has to be developed. In chakki there is no such need It is after all going to be worked by hand. We cannot use our hands above a certain speed, and thus the ball bearing becomes only extravagance and does not fit in with our economy.

Cross Section of a Chakki

1. *Platform*
2. *Adjustable plank*
3. *Bolt attaching platform and the adjustable plank*
4. *Nut fixed in wood used for raising or lowering the level of the adjustable plank*
5. *Axle*
6. *Mani*
7. *Upper Stone*
8. *Lower Stone*
9. *Bamboo pipe*
10. *Iron Handle*

Fig. 5

Note the concave and convex working surfaces of the stones. The gap in between the lower and upper stones gradually goes on diminishing towards the circumference.

Leg & The Cross base of a platform

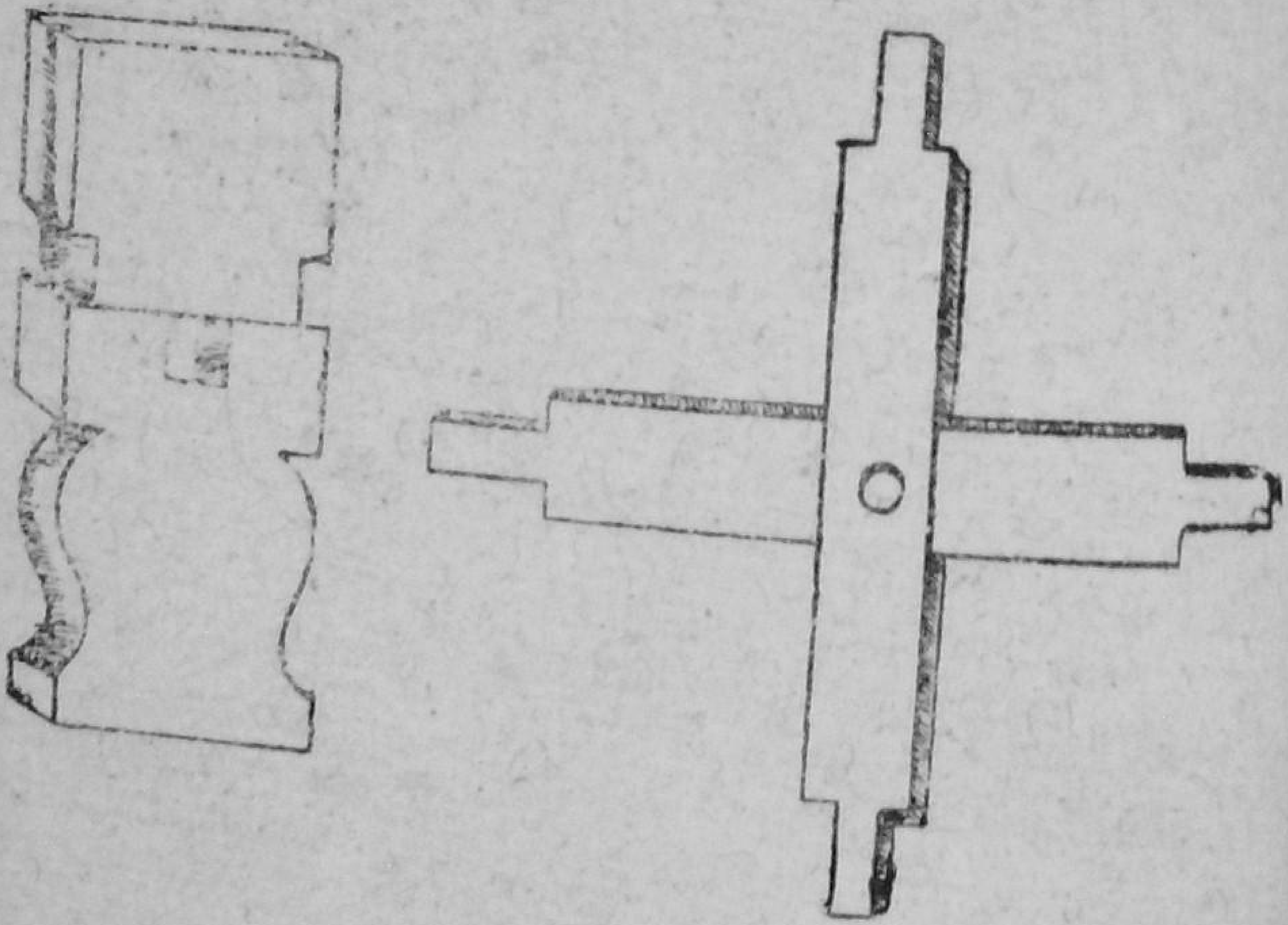


Fig. 6

One improvement that can definitely be done is to make the upper disc balance on the axle while rotating. Then most of the weight of the stone will be on the axle and the person working it will be required only to set it in motion.

Improvement in the Handle

The handle is generally a wooden cylinder about 1" thick, fixed up in a pit in the upper stone. When working the chakki the handle cannot be held tight as that will hinder the free motion of the chakki. Also this hurts the palm since it has to be rigidly held by hand. This can be avoided by fixing an iron bar about $\frac{3}{8}$" thick to the stone, using lead, and then placing over the iron bar a loose bamboo tube of 1" diameter.

The Platform :—

Care should be taken to collect the flour in a pure, clean form. It should not be allowed to fall on the ground and get mixed up with the dust and dirt. For this a wooden platform is a suitable arrangement.

The platform affords one more facility. We can have such arrangements as to increase or decrease the space between the two grinding surfaces. This can be operated when we need either coarse 'Dalia' or fine 'atta' or any intermediary product. The platform can be about six inches high from the ground level and wide enough to allow free collection of the flour. The chakki is placed in the middle of the platform and worked. The process of manufacture of the platform is as under.:—

Take four pieces of wood 1 ft in length $3\frac{1}{2}''$ broad and $1\frac{1}{2}''$ thick. Shape them as in figure no. 6

Make a hole in each of these pieces $1\frac{1}{4}''$ high and 1" broad at a height of 4 inches from the lower end.

Take a piece of wood of 31″ in length $1\frac{1}{4}$" thick and $3\frac{1}{2}$" broad. Make a half lap joint as in figure no. 6

The four ends of the cross have got to be fitted on to the holes $1\frac{1}{4}$"x1" that have been made in the legs. Hence these ends have to be suitably shaped to a length of $1\frac{1}{2}$".

Now to the four ends of the cross attach the four legs already made ready.

The opposite legs should be 26" apart internally. Take a plank size $4\frac{3}{4}$"X 13″ X$\frac{3}{4}$". and cut it into four such pieces which when put together may form a fairly accurate cicurlar disc with 13″ radius. Fit this circular disc on the cross previously made ready. This becomes the platform. To prevent the flour being carried away by the wind generated by the rotation of the stones, a small enclosure is needed This can be made either of tin or wood. It should be nearly 4" in height. For tin enclosure a long piece of tin of 5″ breadth and nearly 7 ft in length is taken and made into a circular frame, fitted around the platform with small nails. The upper edge of the tin should be folded outwards so that it may not present any sharp edges. In the case of wooden enclosure. take wood 18"x14"x4" and saw this to give four quarter circular curved plates of 18"x4"x1″. Make small grooves in the legs of the platform and insert these plates and fix them up with nails. There should be an outlet in the wall to take out the flour. This can be, say about 3"x2″.

The space between the stones can be adjusted by raising or lowering the upper stone. We have already observed how the upper stone can be made to balance on the tapering neck of the axle. If the axle is a little longer and allowed to pass down through a hole in the centre of the platform, then we can raise the axle as and when we

Wooden Platform

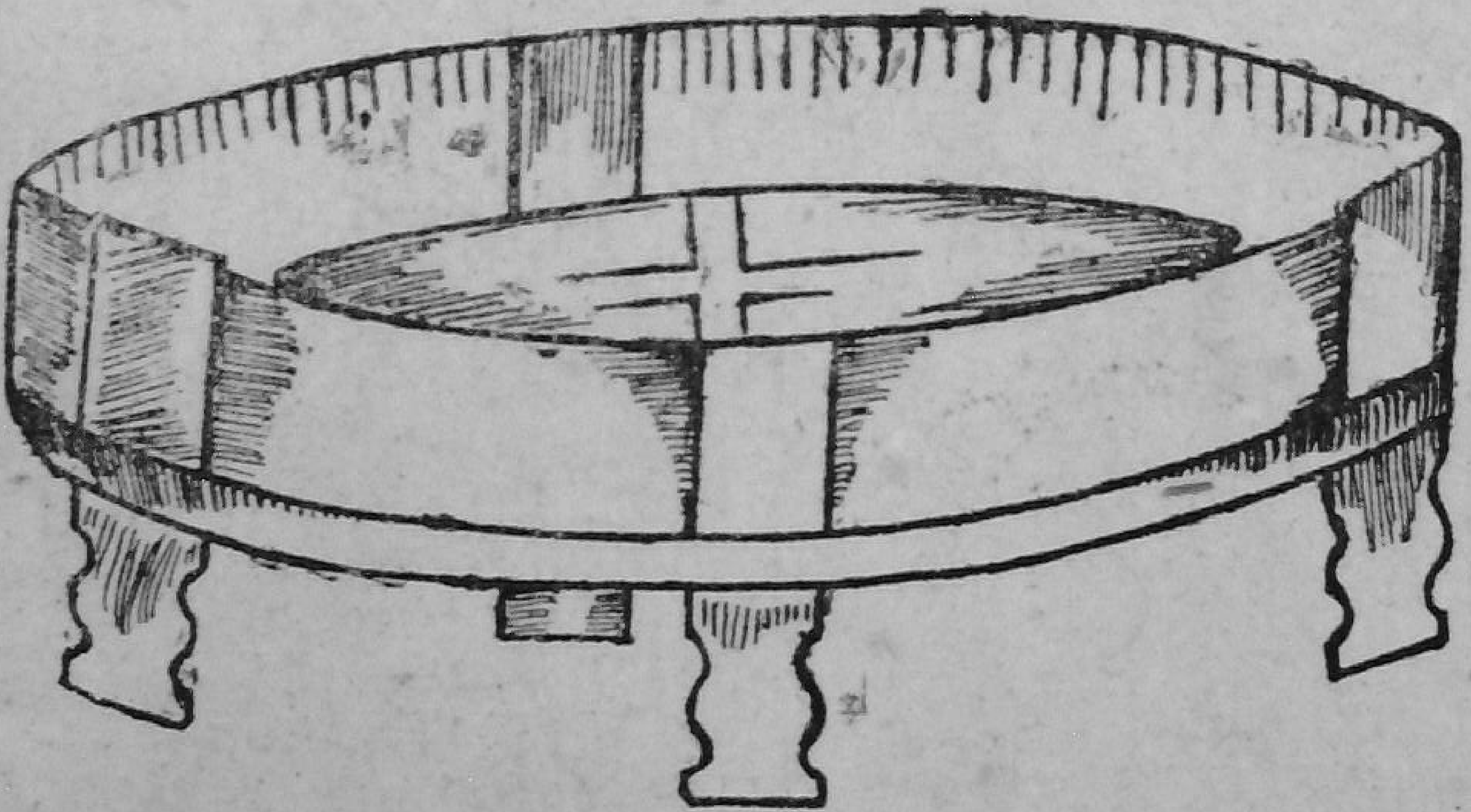


Fig 7

Improved Flour Chakki *(Prepared in Maganvadi)*

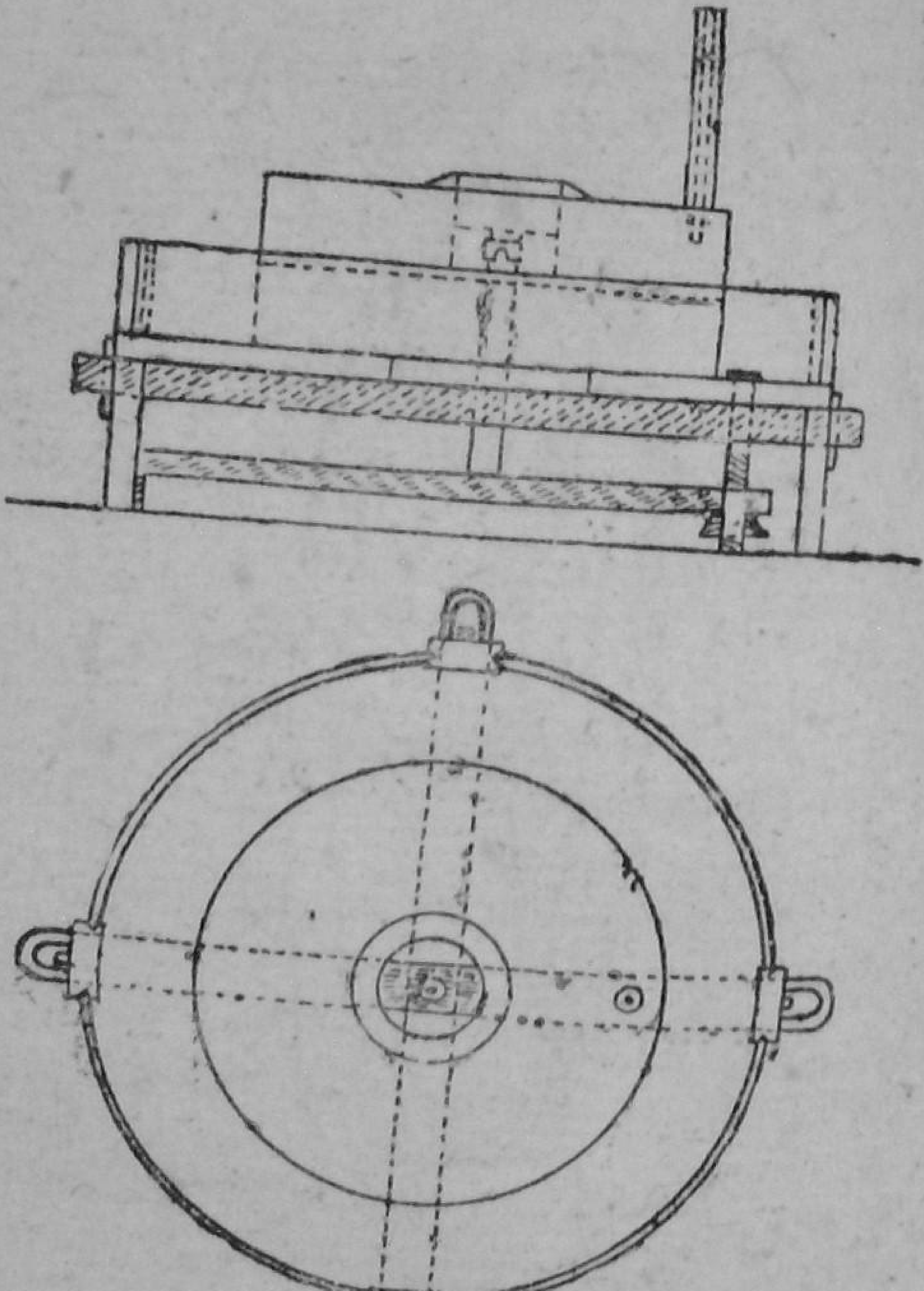


Fig. 8

require and to the required extent. The axle can be made to rest on a piece of plank, one end of which is attached by means of a hinge to one of the legs of the platform. At the other end a hole is made and a bolt passed through. The top of the bolt, in turn, should be fixed in the platform. The nut is attached just underneath this plank. When this nut is screwed up, the level of the plank gets raised, there by raising the axle and the stone resting on it.

An improved chakki of this type can grind on an average nearly 5 lbs of wheat per hour. At Maganvadi daily one woman grinds about 30—40 lbs in a day of 8 working hours.

HOW TO USE THE CHAKKI

1. The chakki should be rotated anticlock-wise by holding the loose bamboo pipe

2. It should be fed at regular intervals when the stone is in motion.

3. The chakki should not be stopped for feeding as it would require extra energy to restart it now and then.

4. It should be worked at a steady speed.

5. The person working the chakki should be seated on a stool about 8" in height.

6. He should sit very close to the platform with the legs stretched out on both the sides and encircling the platform. This would facilitate the worker in exerting all his energy on the chakki.

7. The outlet in the platform should be blocked with a piece of cloth so that the flour may not run out and be wasted.

8. After use the chakki should be kept covered with a lid made of bamboo or any other cheap stuff which will prevent rats, birds or dogs from having access to it. The mouth of the chakki also should be kept blocked by a piece of cloth.

HOME REPAIRING OF STONES

The working surfaces of the stones need dressing at least twice a year. Chakki-dressing is a very simple process and anybody can attend to this in his own place without depending on professionals, who are in some places rare to obtain and who, at times, demand fancy charges.

A small hammer weighing about $\frac{1}{2}$lb, with its ends tapered to $\frac{1}{4}''$ is all the instrument that is required for this work. This should be of good quality steel. It may not cost more than a rupee or so. The hammer is provided with a wooden handle say 10″ in length. The handle is held tight in one hand and the surface of the stone is pecked closely with the sharp end. When dressing the edges one should be cautious not to break it. Depression should be made in both the surfaces and the chakki will then become ready for use. When once the chakki is treated this way it is necessary to brush out the minute particles of stone adhering to them. This can be achieved by grinding a little paddy husk or any other similar useless stuff.

The estimated cost of an improved chakki may, at the most, come to Rs. 30-0-0 per set.

Flour is the primary need of man. One cannot afford to rely on the sweet will and pleasure of somebody else for one's flour requirements. One has to be independent and self-supporting in the matter of this primary need.

We cannot afford to rely on electric and power driven mills for our flour requirements as these deprive us of a lot of nutrition. The high speed of the mill produces heat which destroys to a great extent the vitamin B content of the cereals.

Then, there are those large scale flour mills in towns, which produce 'Maida'. Maida is finely ground starch of cereals. To produce maida, cereals are first of all soaked and polished in order to remove the outer bran with the yellow covering matter and the germ. The essential mineral salts and vitamins are contained in the bran and the germ. After polishing, the resultant starchy kernel of the cereal is ground into a fine flour. Why is it that people have begun resorting to all these laborious methods is a pertinent question. Simply because the flour is pure white and pleasing to the eyes and loaves made out of this flour are so soft that they need no mastication. We should not be guided merely by what looks good to the eye. After all it is the body that has got to be nourished. Maida contains little or no nourishing properties. It causes constipation which is the root cause of many chronic diseases. The bran of the cereal is a very essential part which has got to be consumed by the people. It is folly to remove the bran and consume pure starch only.

A recent press note issued by the Bombay Government says that more than 7,800 tons of extra wheat are required to prepare maida for the consumption of about one-eighth the population of Bombay and suburban districts. It is not only the quantity that matters here, but we should reckon the loss of nutritive food. By voluntarily throwing away these rich foods, we bring on ourselves a number of com-

plaints as constipation, beri beri, anaemia, lack of appetite' general tissue atrophy, poor secretion of milk, pellagra and so on. To cure these diseases we import costly medicines and thereby bring on ourselves double poverty.

Considering the above facts, it is wiser to resort to hand-grinding. This industry can give us enough atta daily and afford us good exercise in the morning which also adds to the general building up of the body.

Chakki-grinding is an indoor exercise for women. There is a feeling in almost all parts of this country, that daily grinding affords facility for painless delivery. Pregnant women can grind daily till near the time of delivery.

People argue that now-a-days women are so much over -worked and weak that it is cruel to ask them to grind on chakkis. If men feel like that they can also help women to grind or else men alone can take to this productive physical culture. Weak women can only build themselves when they eat good nourishing food and do some sort of exercise to properly digest it. There is no use in attending to number of distracting occupations and losing our health. Maintaining her health is the primary duty of a good housewife. That itself will contribute to the well being of the members of the family. Viewed from the point of our future generation, our women should not neglect their health. This negligence often results in the birth of weak and sickly children. Infant mortality in India is notoriously high. This will ultimately bring about the extinction of our race. We hope our women will realise their responsibility to society and never leave a stone unturned (or unrotated) in building up their physique and thereby ensure the good health of future generations.

Though our whole emphasis is on the revival of hand-grinding, we are not against grinding flour, using bullocks or water power available in the villages. We have no objection in recommending the use of such machines to our villages, provided these contrivances are not made an instrument of exploitation by a few rich men in the village who can afford to purchase these chakkis, nor should these be used in such a way as to make the villagers completely dependent on them for the supply of flour.

Bullock chakkis, popularly known as 'Kharas',-are in use in large numbers in the villages of the Punjab. These are owned commonly by the Panchayat Board. Each family that needs flour has to bring its camel or bullocks to work it. They are required to pay a nominal fee for every maund of cereal ground to meet the repairs and maintenance of these chakkis. A picture of this chakki with a brief description is given below:

PUNJAB BULLOCK CHAKKI

There is a big iron pinion with a diameter of nearly 6½ ft. There are about 140 teeth to this pinion. There is a small pinion attached to this which has only 7 teeth. They are so arranged that when the bigger pinion turns once the smaller will make 20 revolutions. To the shaft of the bigger pinion is attached a long handle which is worked by a pair of bullocks. To the shaft of the smaller one is attached the grinding stone which is about 30" in diameter and 6" in height. Ordinarily the upper stone of the chakki is made to revolve. The stones are covered up with a tin frame and above this frame is kept the funnel filled with cereals. As the stone rotates the cereals fall

into the chakki little by little and get ground. The flour is then brushed out through a small opening in the platform on which the stones rest.

Such chakkis are available in the Punjab. The iron parts alone cost about Rs. 350-0-0 and can be had through the office of the Director of Industries and Commerce to the Government of the Punjab. The stones shall have to be had from either Agra or Fatehpur Sikri near Agra. They may cost nearly Rs. 50-0-0 per pair and can be had of Shri Ramji Lalji Sharma, Dawar Stone Merchants, Fatehpur Sikri, Agra.

SIMPLE BULLOCK FLOUR CHAKKI

The bullock driven chakkis of the Punjab type (Kharas), which work with the gear arrangement, are heavy for ordinary bullocks. They require a huge shed and repairs cannot be executed except by artisans who know the ins and outs of these machines.

In the villages, that pattern of chakki can be conveniently introduced which involves the least amount of repairs and the machinery of which is not complicated Such a chakki is found working in some parts of U. P. and C. P. The machinery is of the simplest type or really. speaking there is no machinery at all in it. Over a mud platform raised to the level of the bullock's height, the chakki stones are placed as usual. A wooden bar is fixed across the upper stone by cutting a groove in it and with the help of two sets of nuts and bolts. To the wooden bar is joined a loose yoke for the bullock. The bullock pushes the bar along which rolls the upper stone.

A wooden frame, as is found in the hand chakki, eceives the flour and a brush attached to the upper stone pushes it to a vessel placed near the platform. In short

" Kharas " or Bullock Driven Chakki

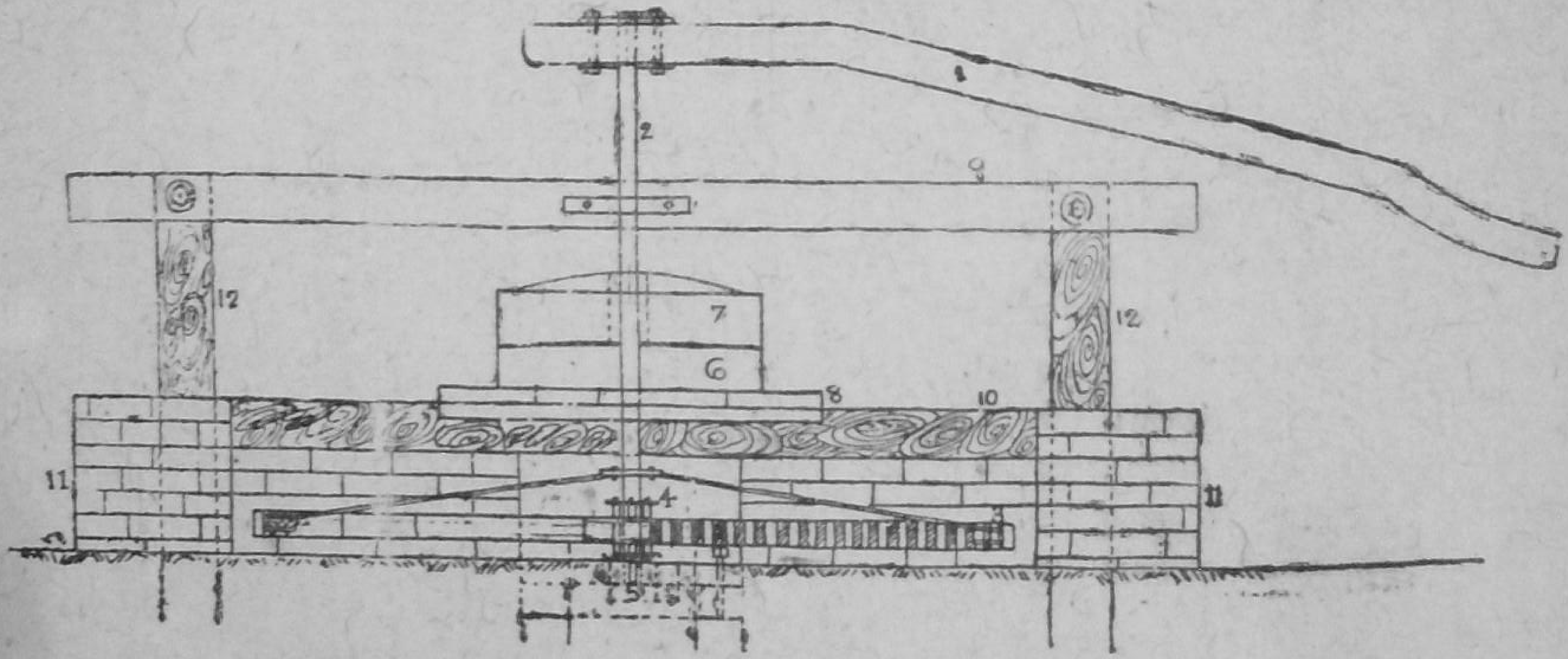
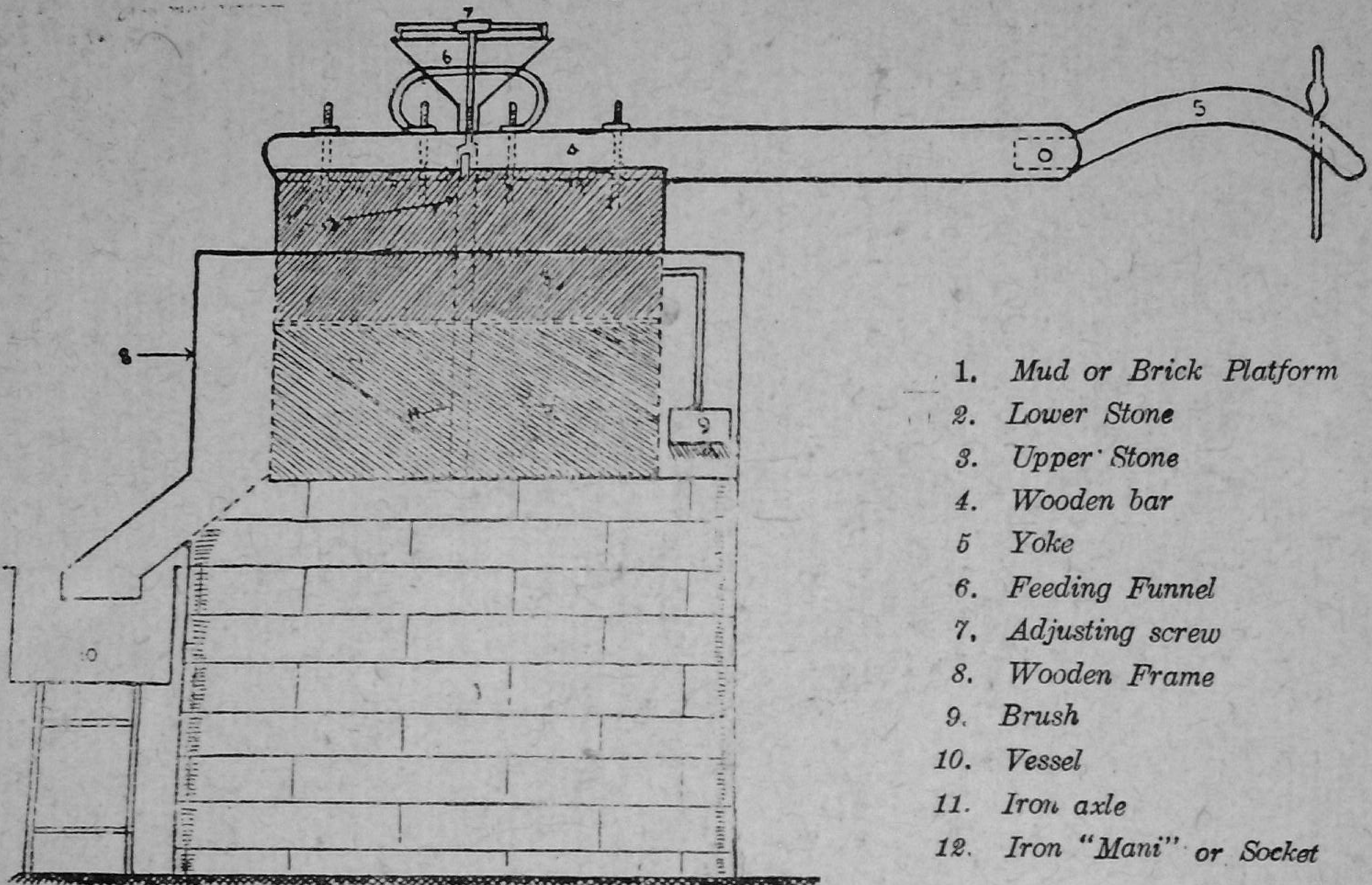


Fig. 10

1. *Wooden handle to the free end of which the bullocks are yoked.* 2. *Iron shaft that is rotated by the handle.* 3. *The big Pinion which is connected to the shaft.* 4. *Smaller pinion.* 5. *Shaft of the smaller pinion. (Only the lower end is visible)* 6. *Lower stone of the chakki.* 7. *Upper stone of the chakki which is set in motion by the smaller pinion.* 8. *Wooden platform to collect the flour.* 9. *Cross beam, to keep the shaft in vertical position.* 10. *Cross beam to support the platform.* 11. *Side constructions out of brick.* 12. *Side pillars to support beams 9 & 10.*

(The stones remain covered with a tin covering over which is placed a funnel with cereals to feed the chakki automatically. This is not purposely shown in the picture as it will be only confusing.)

Single bullock driven chakki



1. *Mud or Brick Platform*
2. *Lower Stone*
3. *Upper Stone*
4. *Wooden bar*
5. *Yoke*
6. *Feeding Funnel*
7. *Adjusting screw*
8. *Wooden Frame*
9. *Brush*
10. *Vessel*
11. *Iron axle*
12. *Iron "Mani" or Socket*

Fig. 11

this kind of bullock chakki is the same as a hand driven chakki except that it is worked with the help of a long lever.

While there is no complication in the mechanism there is also no speed. The stone revolves only as the bullock can go round. The complication found in other bullock chakkis is only meant to increase the speed. You have either complicated machinery and speed or no complication and no speed. Of course to compensate for the slow speed a bigger stone can be used.

This kind of chakki cannot be made into a bussiness proposition. The main idea about it is not efficiency but convenience. Such chakkis can be installed for groups of families in the villages and the farmers can bring their own bullocks and get the flour ground.

The sketch explains the arrangements for making the chakki light or heavy. The chakki has a fixed axle. Over the top of the axle rests the *mani,* an iron cube of 2" x 2" x 2" with pit in the middle to fit into the axle. A threaded iron bar about 1" in thickness, resting over the 'mani' and passing through a fixed nut in the wooden bar, raises or lowers the upper stone, thus making the chakki light or heavy.

The feeding is done with the help of a funnel in which the passage of the grain can be controlled by the wooden disc moving backward and forward with a nut and bolt attachment.

A bulloek grinds about 15 lbs of flour per hour. Where stones of big dimensions, of 3 to 4 feet in diameter and 9" in thickness are available, these chakkis can be easily installed with the help of local artisans.

Price List of Equipment Available

FOR

PADDY—HUSKING

AND

FLOUR—GRINDING

As our aim is to stimulate local production, it is not intended to supply finished goods from the Headquarters. A sample implement or a model may be obtained in the first instance and the necessary implements produced on that basis locally thereafter.

The prices mentioned do not include freight, and are subject to fluctuations. As goods are not sold on credit, a sum to cover their price and packing must be sent in advance, or if so desired orders may be executed by V. P. P. We shall not be responsible for damage caused in transit.

Paddy-Husking

		Rs.	A.	P.
Paddy chakki		15	0	0
Packing		1	0	0
	Total	16	0	0
Dhenki		12	0	0
Packing		1	0	0
	Total	13	0	0
Dhenki parts				
Mortar and pestle		9	0	0
Models Dhenki		1	8	0
„ Paddy Chakki		1	8	0

The paddy chakki is made of wood. A woman working at it can prepare unpolished rice out of two maunds of paddy in a day of 8 hours. The grooves need to be renewed after husking about 12 to 15 maunds of paddy.

The dhenki is used for polishing rice. One person can polish in a day of 8 hours unpolished rice produced from four maunds of paddy. The mortar of the dhenki is so constructed that the rice circulates in a fixed direction automatically within it, thus eliminating the need for a person to sit by the mortar and stirring. The dhenki is, therefore, worked by one person only.

Rice:—A book regarding the food value of rice, instruments for rice pounding, and the economics of the rice-pounding industry. Detailed instructions for the manufacture of Paddy-husking Chakkis are also given therein.

Flour-Grinding

	Rs.	A.	P.
Complete chakki	30	0	0
Packing and cartage	2	8	0
Total	32	8	0
Chakki stones including Axle. mani etc.	17	0	0
Packing and cartage	1	0	0
Total	18	0	0
Chakki platform	15	0	0
Packing	2	0	0
Total	17	0	0
Adjustable parts Axle. Mani	0	8	0
Nut bolt	0	8	0
Packing	0	8	0
Total	1	8	0
Model	1	8	0
Packing	0	8	0
Total	2	0	0

The flour chakki is based on the Gujarat model with a few modifications. It rests on a wooden platform on which flour collects thus ensuring the cleanliness of the flour produced.

(1) A piece of bamboo is inserted over the iron handle to form a handle cover. This cover prevents the hand from chafing against the iron handle.

(2) The chakki has a device to raise or lower the upper stone for grinding coarse or fine as desired. The device is made with the help of nut bolts.

(3) One person can grind about 4 to 5 pounds of wheat on this chakki in an hour. Stones of good quality from Agra are used.

" Grinding of Cereals "

A book regarding home grinding of cereals and the instruments used in different parts with illustrations.
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